Name of Paper: The Climate Action Project Research Initiative

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Abstract

Through a cooperative agreement with the National Energy Technology Laboratory, The Nature Conservancy is implementing the Climate Action Project Research Initiative to: 1) improve carbon inventory estimates during both planning and implementation phases of projects; 2) devise standardized approaches to estimate project carbon benefits at a reasonable cost; and 3) screen regions to identify new project opportunities where conservation and cost-effective carbon sequestration can be achieved concurrently. This work consists of testing advanced digital videography, constructing and testing GIS-based models for baseline development, exploring carbon sequestration amounts and costs in a variety of sites, and periodic peer review. Work is being carried out in Brazil, Belize, Chile, and eight states.

1.0 Introduction

Forests act as carbon "sinks" by absorbing atmospheric CO_2 through photosynthesis, and as emissions "sources" when carbon stored in trees and other pools is released into the atmosphere. Deforestation accounts for approximately one-quarter of annual carbon dioxide emissions (Figure 1). In order to reign in emissions rapidly enough "to stabilize atmospheric greenhouse gas concentrations at a level that will prevent dangerous human interference with the climate[1]" aggressive actions must be taken now to reduce both industrial emissions and to increase the conservation and restoration of native ecosystems.

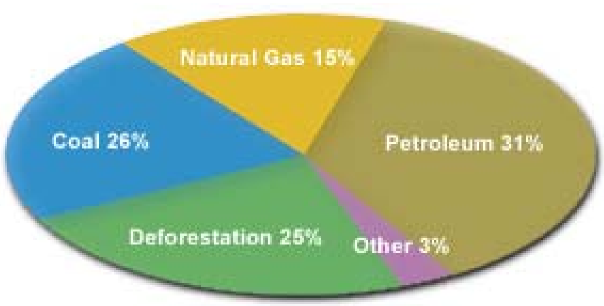

Figure 1. Annual CO_2 Emissions Globally
Sources: IPCC, 2001; CDIAC, 1998.

In their Third Assessment Report the Intergovernmental Panel on Climate Change (IPCC) estimated that land use, land use change and forestry (LULUCF) activities such as reforestation and reductions in deforestation could

[1] Explicit goal of the United Nations Framework Convention on Climate Change, Article 2, 1999.

contribute on the order of 100GtC (cumulative) of greenhouse gas emissions reductions and removals through 2050. This would be equivalent to about 10% to 20% of projected fossil fuel emissions during that same period (IPCC 2001). Even so, the inclusion of forest-based activities as a way of reducing greenhouse gas concentrations has been one of the more contentious issues in the international climate change debates due to numerous concerns regarding its use.

The concerns about terrestrial sequestration are varied, ranging from technical issues[2] to ideological ones. The primary technical concerns are in the areas of measurability, additionality, baselines, leakage, environmental performance, and permanence. The first five issues are common to project-based approaches within both energy and land use sectors while permanence concerns are widely considered to be peculiar to land use projects (e.g. Chomitz 2002). For terrestrial carbon sequestration to be accepted as a strategy for reducing climate change the technical issues need to be overcome through good science, sound policy, and technological innovation.

The proponents of terrestrial carbon sequestration projects cite not only the importance of land use changes to the atmospheric build-up of CO_2[3], but also the ancillary benefits that can accompany forestry projects. In addition to contributing to climate change, habitat destruction results in the direct loss of habitat, biodiversity (Heywood, 1995; Stork, 1997), water quality (Myers, 1997), and other resources vital to the prosperity of future generations. Restoration of vegetation and changes in management can help to replenish valuable resources such as timber and soil that may have been degraded through poor management. Furthermore, in the face of climate change, restoring or conserving threatened forests will help to increase the resilience of forests and the biodiversity that they harbor by reducing edge effects and creating potential migration corridors.

The Conservancy and its partners have developed and are implementing pilot conservation projects that serve as proving grounds for demonstrating that activities with climate benefits can lead to significant conservation. These projects, called "climate action projects", are located in the United States, Belize, Bolivia and Brazil, and safeguard or restore more than 1.7 million acres of native ecosystems. These projects are collaborative efforts between The Nature Conservancy, Sociedade de Pesquisa em Vida Selvagem e Educação Ambiental (SPVS), Programme for Belize, Fundación Amigos de la Naturaleza, The Government of Bolivia, American Electric Power, BP Amoco, Cinergy, Detroit Edison, General Motors, PacifiCorp, Suncor, Texaco and the Utilitree Carbon Company.

2.0 Climate Action Project Research Initiative

The Nature Conservancy is working with the Department of Energy (DOE) National Energy Technology Laboratory (NETL) to explore the compatibility of carbon sequestration and the conservation of biodiversity. Through this research, TNC is working in close collaboration with U.S. based companies and NGO partners to undertake research that will help to identify activities that have concurrent biodiversity and climate benefits. To demonstrate the atmospheric effectiveness of these activities, an emphasis of the research is on how to best measure the CO_2 impacts, and how to do this cost-effectively.

One of the greatest assets of this initiative is that it is applied research, being used in ongoing pilot carbon sequestration projects. The goals of the Climate Action Project Research Initiative are to:

1) improve carbon inventory estimates during both planning and implementation phases of projects;

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[2] For a review of these issues see Schlamadinger, B. and Marland, G. June, 2000. Land Use & Global Climate Change: Forests, Land Management, and the Kyoto Protocol. The Pew Center on Global Climate Change.

[3] Approximately 30% of the current human-induced increase in atmospheric concentrations of CO_2 has been caused by land use changes (WRI 1998).

2) identify the best approaches to estimate project carbon benefits at a reasonable cost ; and
3) evaluate new activities throughout the U.S. to identify where biodiversity benefits and low cost carbon sequestration opportunities overlap.

These three general goals are being addressed through inter-related tasks, carried out in a variety of U.S. and international sites. The new activities that are being evaluated are activities that are conservation priorities, but for which carbon sequestration potential has not been thoroughly assessed. The tasks and sites are briefly described below.

Figure 1. Tree Fern (*Cyathea* spp.)

2.1 Improving Carbon Inventory Estimates

The carbon inventory work is being carried out on existing on-the-ground pilot projects. In particular, on-the-ground research is being carried out in The Rio Bravo Carbon Sequestration Pilot Project in Belize, and in the Atlantic Forest Climate Action Projects in Brazil.

The work in Belize takes place at the Rio Bravo Conservation and Management Area (RBCMA) on 104,892 ha of mixed lowland, moist sub-tropical broadleaf forest and Caribbean pine savanna. In 1994, PfB purchased 14,327 ha of upland forest and swamp forests to add to the area as a part of the carbon project. Carbon benefits are derived from landscape scale forest management to prevent the conversion of broadleaf tropical forests to agriculture, restore degraded pine savanna, and introduce reduced-impact logging. Funding for this project has been provided by Cinergy, Detroit Edison, PacifiCorp, Suncor, and the Utiltree Carbon Company.

The Atlantic Forest Climate Action Projects take place in the state of Paraná, Brazil. After centuries of human use, the Atlantic Forest has been reduced to only seven percent of its original range. An analysis of the Guaraqueçaba Environmental Protection Area in the state of Paraná in southern Brazil identified Asian water buffalo ranching as the reserve's number-one threat. The three climate action projects in this area include the removal of Asian water buffalo from pasturelands that had previously been forested, restoring forests there, preventing further deforestation, and working with local ranchers to improve buffalo management and test new economic activities, such as agroforestry. The projects seek to restore and protect approximately 30,000 hectares of tropical forest. Funding for these projects was provided by American Electric Power, General Motors, and Texaco.

Carbon inventory plans are designed to periodically quantify the amount of carbon stored in key pools. These inventories are used in project baselines and in ongoing projects to estimate the differences between carbon pools over time. They provide the primary components for determination of project GHG benefits. The work being carried out through this initiative focuses on increasing accuracy related to allometric regressions, and advancing the soil carbon measurement field.

In conducting a traditional carbon inventory, estimates of understory vegetation, standing litter, and soil biomass are collected from plots, while the majority of the standing biomass for each plot is estimated from taking the diameter-at-breast-height (DBH) values of measured trees and then applying species-specific, or more general allometric equations. Regression equations have been developed to describe aboveground biomass as a function of DBH alone, height alone, or DBH and tree height. DBH or height and species, or groups of species, are thus the principal measures used to calculate tree biomass in plot sites. Biomass is converted to carbon using a factor of 0.5 (Brown 1997).

Developing and Improving Allometric Regressions. Many of the regression equations used in the carbon inventories for The Nature Conservancy's projects were developed in different regions and are not species-specific. In some cases, the results that one would get using a general biomass equation instead of a species-specific equation are quite different. For example, Uhl (1988) found a two-fold difference in biomass estimates for *Cecropia* spp. when a multi-specific rather than a species-specific equation was used. In light of these types of difference, new equations are needed for species that are structurally unusual relative to broad leaf trees from which general biomass equations in the tropics are derived. Included in these unusual forms is the genus *Cyathea* (Figure 1).

Regressions for this species were recently developed in the Guaraqueçaba Climate Action Project in Brazil. First, the heights and diameters at 1.8 meters (DBH) were measured for 22 fern trees. Individuals were then harvested, field weighed, and representative subsamples were taken. The subsamples were dried to a constant weight and the field weights adjusted using the wet:dry weight ratios to determine dry biomass. These data were then analyzed using regression analyses to define the correlation between tree measurements and dry biomass (Figure 2). Similarly, new equations are being developed for lianas.

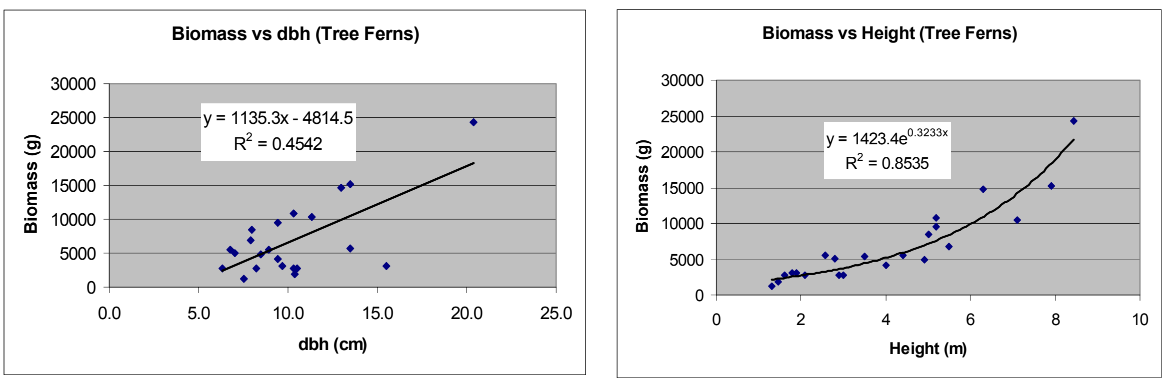
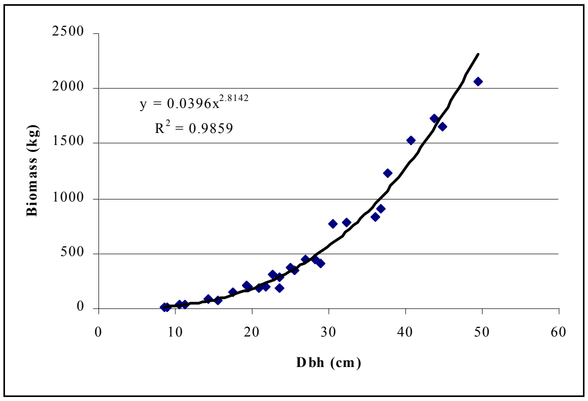
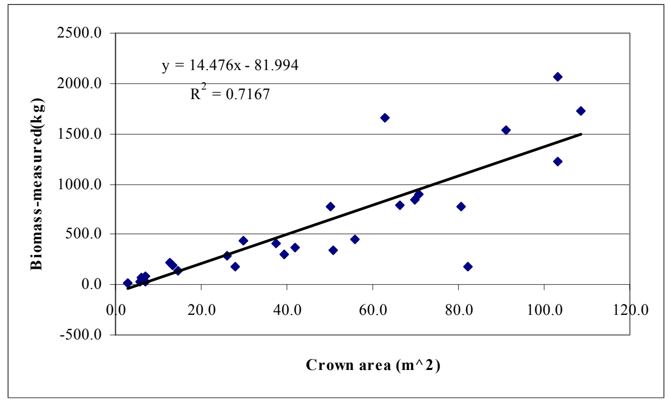


Figure 2. New regression equations relating height and diameter to biomass for *Cyathea* spp., a genus for which an allometric relationship had not been developed.

Furthermore, equations have also been developed for pine trees (*pinus caribbea*) found in the pine savanna in Belize and much of the Caribbean. For these equations crown area is being used as the independent variable (Figure 3) so that estimates of biomass can be made from the air. Additional work is underway strengthen equations for other vegetation found in the pine savanna.





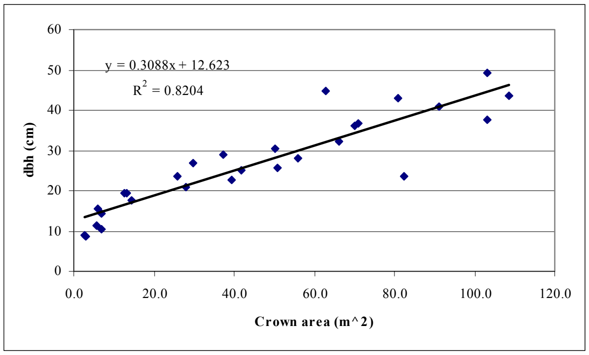


Figure 3. New regression equations relating diameter and crown area to biomass, and crown area to dbh based on the destructive sampling results for *pinus caribbea* in the Belizean pine savanna. These estimates can be used with remote-sending imagery to develop carbon inventory estimates.

Work is also needed to improve existing general biomass equations. For example, in moist tropical forests there is a great deal of data for smaller diameter trees, but few data points available for larger trees (Figure 4). Large trees, greater than 50 cm in diamtern found in the moist Atlantic forests of Brazil are being destructively sampled to improve these equations.

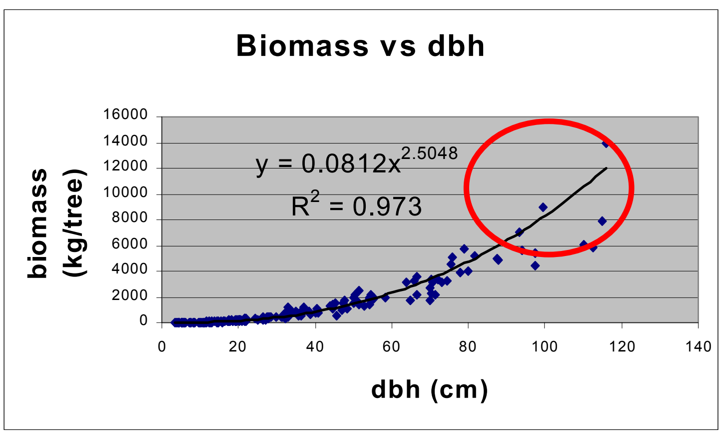


Figure 4. Depiction of data points for general biomass equation for tropical moist forests used in the Guaraqueçaba project (Brown 1997). Note the lack of data for trees greater than eighty centimeters in diameter.

Testing and Evaluating the Capabilities of a New Remote-Sensing Technology, Multi-Spectral 3-Dimensional Aerial Digital Imagery (M3DADI)[4]. One of the challenges for carbon benefit estimation is the current lack of data on the carbon content of heterogenous landscapes that do not exactly meet the definition of grasslands or forestlands. For example, the pine savanna in Belize is very heterogeneous, consisting of a mixture of trees (*Pinus caribbea*), grasslands, shrub islands, and palmetto vegetation. To obtain a representative sample the carbon content of such a complex vegetation community would require the installation of many hundreds of sampling plots and would likely be extremely expensive. The purpose of this study was to determine if Winrock's multi-spectral, 3D aerial digital imagery (M3DADI) system could be used to effectively estimate the carbon storage in such a heterogeneous landscape. Later,

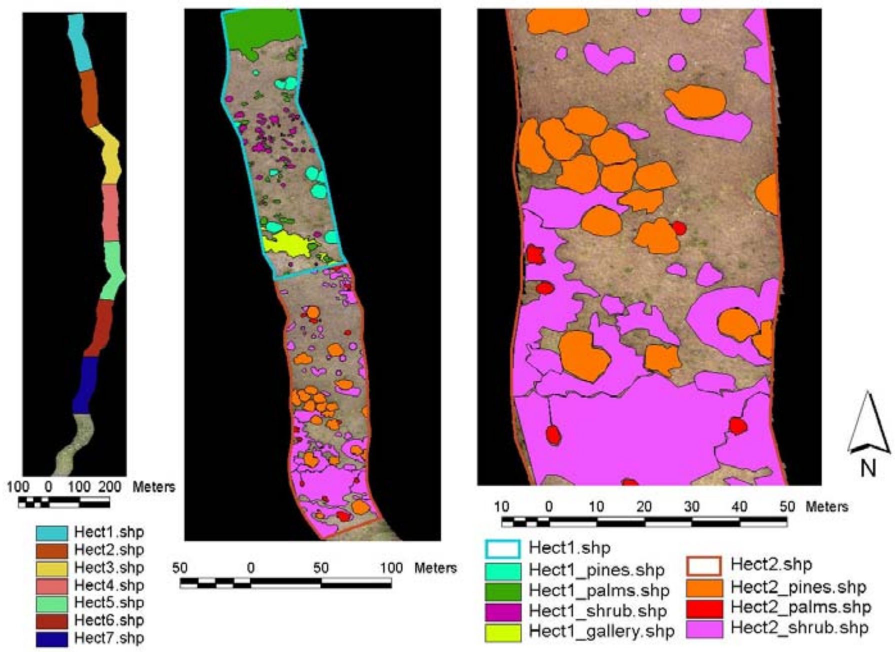


Figure 5. Examples of interpretation of sub-vegetation types within 1 ha "plots" of the pine savanna used for estimating the carbon stocks. Based on the field data and other measures from the digital imagery, carbon stock estimates were applied to each of the sub vegetation types and a total carbon estimate was made for each 1 ha "plot".

we will use these findings and compare them to what would be expected given traditional inventory techniques in terms of both accuracy, and cost.

The pine savanna was flown in 2002 with the M3DADI system and interpretation of the images completed (see example Figure 5). The next step was to classify the vegetation categories within a series of 19 one-hectare plots. The categories found in the pine savanna include pine, shrub, palms, grass. Digital aerial imagery was used in conjunction with on the ground measurements to establish relationships between aerial measurements (crown area, height, etc.) and carbon (Table 7).

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[4] For more detail see paper and oral presentation by Dr. Sandra Brown, from this same conference entitled: *Carbon Quantification of Diverse Landscapes Using Multi-Spectral 3-Dimensional Aerial Digital Imagery.*

Table 7. Carbon content (t C/ha) for pine savanna vegetation. Data interpreted from 19 1-ha polygons.

Polygon number	BioDbh Pine t C/ha	BioCrown Pine t C/ha	Shrub t C/ha	Palms t C/ha	Grass t C/ha	BioDbh Total t C/ha	BioCrown Total t C/ha
1	3.2	3.4	0.4	0.2	2.6	6.9	7.1
2	6.9	7	3.0	0.1	1.7	11.7	11.8
3	19.9	17.9	2.9	0.4	1.1	24.2	22.2
4	14.8	14.2	2.0	0.3	1.6	18.6	18.0
5	20	19.6	2.6	0.3	1.2	24.0	23.6
6	7.7	7.7	2.6	0.3	1.8	12.3	12.3
7	14.8	14.6	1.3	0.2	1.3	17.6	17.4
8	0.9	0.6	6.5	0.3	1.1	8.7	8.4
10	9.3	10.2	6.7	0.5	0.5	16.8	17.7
11	7.3	6.8	6.1	0.4	0.8	14.4	13.9
12	3.8	3.4	6.5	1.0	0.5	11.5	11.1
13	6	5.6	4.4	0.7	1.2	11.9	11.5
14	6.4	6.7	4.7	0.8	1.1	12.7	13.0
15	10.9	9.7	0.4	0.4	2.4	13.9	12.7
16	0.4	0.4	0.4	0.4	2.8	3.9	3.9
17	0.2	0.1	1.0	1.1	2.3	4.2	4.1
18	7.2	7	4.8	0.0	1.2	13.2	13.0
19	6	5.3	3.3	0.1	1.7	11.0	10.3
20	6.5	6.1	3.4	0.0	1.6	11.5	11.1
Stats							
n=	**19**	**19**	**19**	**19**	**19**	**19**	**19**
Mean	**8.0**	**7.7**	**3.3**	**0.4**	**1.5**	**13.2**	**12.9**
SE	**1.3**	**1.3**	**0.5**	**0.07**	**0.2**	**1.3**	**1.2**
C.V. (%)	**72.9**	**72.4**	**64.9**	**76.8**	**44.0**	**41.4**	**40.6**
CI % (+/-)	**26.0**	**25.7**	**22.4**	**29.6**	**15.7**	**16.4**	**16.1**
MIN						**3.9**	**3.9**
MAX						**34.4**	**34.4**
# of plots needed for precision level of +/-7%						**100**	**96**

The preliminary results show that M3DADI can be used to estimate carbon inventories for heterogeneous landscapes, such as the Belizean pine savanna. Additional work is needed to further refine the regressions used to correlate the videography data with carbon storage amounts, to complete analysis for a larger number of plots to achieve an acceptable level of sampling precision, and to assess the accuracy of the method as compared to traditional ground measurements.

Measuring Soil Carbon Using Laser-Induced Breakdown Spectroscopy[5]. The Nature Conservancy has identified soil carbon as a key pool that needs to be addressed in order to improve project carbon inventories. Existing technologies have made extensive soil carbon measurement too uncertain or too costly, so many projects either do not measure them, or use literature values that have high degrees of uncertainty. As part of the Los Alamos National Laboratory (LANL) program on Terrestrial Carbon

[5] For more detail on this technique see paper and oral presentation by David D. Breshears, from this same conference entitled: *Total Carbon Measurement from Intact Soil Cores with Laser-Induced Breakdown Spectroscopy.*

Sequestration and Management, LANL has developed a method for soil carbon analysis based on laser-induced breakdown spectroscopy (LIBS).

A workshop will be held in Brazil to discuss the following issues related to LIBS:

- What is the current state of the art with regard to carbon measurement in soils (without LIBS)?
- What are time estimates to obtain carbon data for various projects to date?
- How does carbon analysis by LIBS compare to dry combustion analysis and carbon measurement by other methods in terms of cost and accuracy?
- How are carbon baselines established?
- What is the sampling design and intensity needed?

In addition, soil samples are being collected and carbon concentrations being estimated using both LIBS and dry combustion. These data will help to further refine and calibrate LIBS measurements, and can be used to gain insight into the various pros and cons of the two systems.

2.2 Comparing Approaches to Identify the Most Cost Effective Offset Estimate Methods

The Nature Conservancy derives its general guidelines for determining how to quantify project impacts from international policies, legislative language introduced in the U.S., and analysts' discussions related to these emerging policies. Nearly all proposed or pilot frameworks state that project-based emissions reductions and removals must be beyond "business as usual" to be credited or claimed (e.g. see UNFCCC 1995, UNCCCS 1997, Wyden and Craig 1999, Brownback et al. 2000). With this in mind, cost-effective methods are needed not only to quantify the amount of carbon storage within a project area, but also to estimate the amount of carbon storage that would have occurred had the project not been undertaken.

Developing, Refining and Comparing Alternative Baseline Approaches. The difference in carbon storage and other greenhouse gas emissions between the project carbon inventories and the baseline represents the GHG impacts that are truly additional rather than simply the result of incidental or non-project factors such as recent legislation, market changes or environmental change (IPCC 2000). This business-as-usual or "without-project" scenario is also called the baseline. Baselines are essentially predictions, or future projections based empirically upon historical information, of what would have happened had the project not been put into place. Whether or not the project performs better than the baseline is often referred to the "additionality" of the project.

The Conservancy is engaged primarily in forest protection and reforestation projects, so methods are being sought to quantify baseline trends for both deforestation and reforestation. A review of deforestation models showed that there were over 150 models that have been developed to analyze and predict land use trends. These models vary considerably. They were designed to apply to various different scales, use a variety of data sources, and obtain results with mixed degrees of success (Kaimowitz and Angelsen 1998). The authors grouped the models into eight different categories: analytical household/firm models, empirical household/firm models, regional-spatial models, region-non-spatial regression models & analytical macro-models, computable general equilibrium models, trade and commodity models, and global regression models. They concluded that deforestation rates tend to be higher when forested lands are more accessible, agriculture and timber prices are higher, rural wages are lower, and there are opportunities for long distance trade (e.g. presence of nearby transportation infrastructure) (Kaimowitz and Angelsen 1998).

Baseline development methods must meet the demands of carbon sequestration project developers, investors and regulators. The Conservancy is evaluating alternative methods according to the following criteria:

1) Provides a credible, unbiased prediction of land use trends;
2) Uses transparent and understandable assumptions and methods;
3) Has enough flexibility to be applied to a wide range of project areas and conditions; and
4) Is relatively cost-effective to project developers and practical to use.

Spatial-type models of deforestation and reforestation appear to be the best suited for projecting future rates of land cover change for many of the carbon offset projects managed by The Nature Conservancy (Brown et al. 2000). These spatially explicit models utilize widely-available satellite imagery as a primary data source, and can be used not only to predict rates of land cover change, but the location of that change, both which are critical for producing accurate baseline estimates. The location of the change is important because some areas are more susceptible to deforestation than others, and because the amount of carbon stored in forests varies across the landscape.

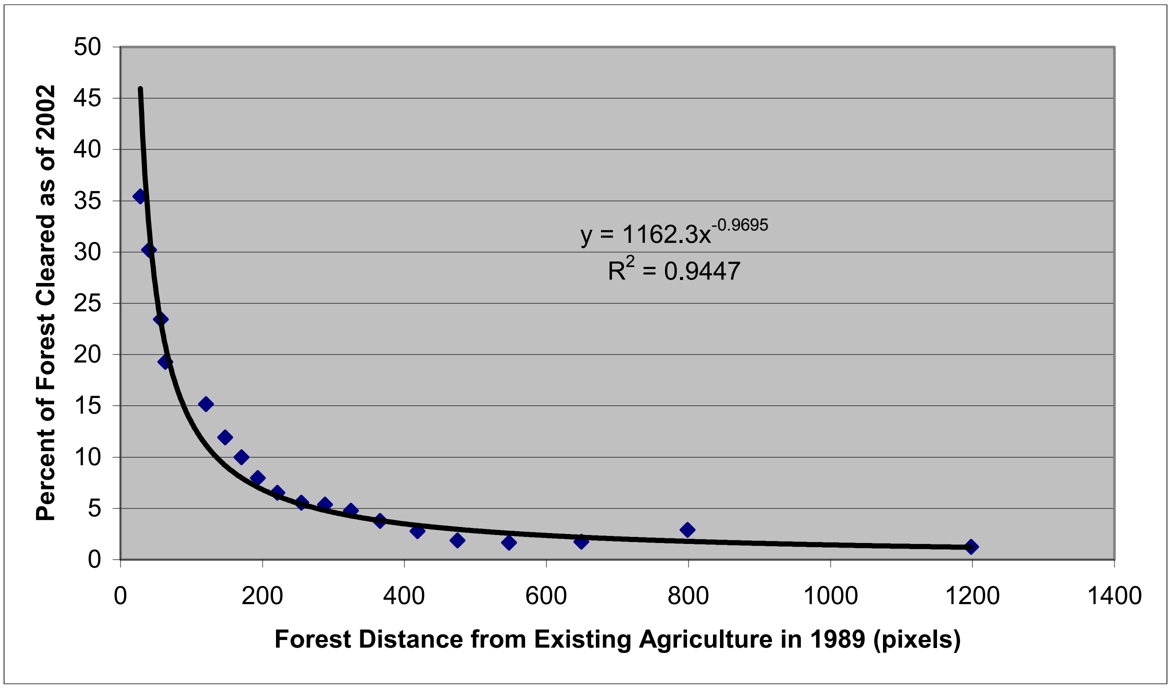

Figure 4. EDMAP correlation, taken from work in Santa Catarina, Brazil, between distance of forest from existing agriculture and proportion of forest within that distance category that was cleared. Units on the X axis are pixels, which are 30 meters in length.

TNC is currently developing a change detection model called the Edge Distance Method for Assessing Probability of Land Use Change (EDMAP). EDMAP uses remote sensing change detection techniques and regression analysis to determine rates and directions of change, as well as probabilities of change. Two or more time periods of Landsat data are gathered. The first data date is from the late 1980's or early 1990's, and the second will is from as close to the present as possible. Using field data gathered during visit to the sites, the scenes are classified to up to 20-30 landcover classes, including different types and condition of forests. The two landcover maps are then be compared and changes from one class to another quantified using GIS. Change maps are made to visually display the results, and tables produced giving percentage and actual area of change from one landcover to another. Regional deforestation and reforestation rates are taken from these data.

This data is then used to establish percentages of deforestation that occurred within particular forest types given certain characteristics. Currently, EDMAP limits the regression analysis to only one factor, distance from existing agriculture (Figure 4). The resulting regression is applied to the most recent map of forest remnants to assess the probability of future clearing. The baseline assumes that forest remnants would have been cleared indirect proportion to the probability, that is, if there were a 25% probability of clearing within a given pixel over a 10-year period it is assumed that 25% of the forest within that pixel would be cleared.

A more complex approach being evaluated is a computerized geographic model, GEOMOD. Like with EDMAP, the first step in GEOMOD is to analyze rates of deforestation and reforestation. Areas impacted by clearing or other land cover change between two points in time are identified. This allows for the determination of the rate of the change, the location of areas converted, and the percentage of the total study area converted from one land cover to another. This is determined using satellite imagery and can often be correlated to socio-economic data, such as population dynamics.

This spatial pattern of the detected deforestation and reforestation is then analyzed against numerous factors that influence where people prefer to convert forest to agriculture. Each factor (driver) is analyzed to see which produces the best predictive power. Examples of relevant drivers include elevation, slope, soils, distance from rivers, distance from local communities, distance from roads, and distance from major population centers.

Once the rates of change and the best set of factors have been selected, the model can be run for a specified timeframe, simulating a baseline or without project scenario 10, 20, 30, 40 or more years into the future. GEOMOD produces a time series of land-use maps at time intervals to be chosen (i.e. every 5 years) over the selected time-frame (i.e. 40 years) of the project. Baseline carbon emissions or removals are calculated based on vegetation types that are located where the model predicts land will be cleared or reforested. Model validation shows that the accuracy of the model in predicting deforestation has varied between 74% and 96%, depending on time scale, number of land classes, accuracy of the initializing data, types of initializing data, relevance of available data, and cell resolution (Hall and Dushku 2002).

At two sites, EDMAP and GEOMOD are being used side-by-side. The models will be compared to assess differences in both results and costs, and subjected to peer review to determine which of the approaches might be more acceptable to policy makers. Though still in the R&D phase, it is already apparent that the EDMAP approach will be more cost-effective and generally easier to use than a full scale GEOMOD analysis that takes into account a large number of drivers. However, its simplicity makes it less flexible in terms of simultaneously assessing numerous potential spatial factors that affect land clearing or reforestation.

Assessing the Cost-Effectiveness of M3DADI Remote Technology Against Traditional Inventories. Setting up and measuring an adequate number of field monitoring plots in areas that are heterogeneous or inaccessible can be cost prohibitive given the current value of CO_2 emissions reductions. M3DADI is potentially much more cost effective than traditional field inventories in remote or extremely variable locations. A comparison of cost and accuracy is being made between traditional carbon inventory methods and M3DADI. Costs to be considered include: field monitoring personnel time, equipment (both start-up and periodic), analytical time and reporting.

Soliciting Peer Review and Modify Research Accordingly. Third-party peer reviewers are invited to annually review progress made under the Climate Action Project Research Initiative. Modifications to the direction that research takes are made based on the comments and ideas gained through these meetings, called Technical Advisory Panel (TAP) meetings. The first meeting was held in 2002 and provided information that has been helpful in the continued development of baseline approaches. In particular, it became apparent that a robust method of assessing uncertainty in baseline approaches is important to policy makers as there is an expectation that offset estimates will be "credited" at the lower end of a uncertainty range.

TAP meetings will also be held in 2003 and 2004. TAP participants come from private sector, academic, policy making, scientific, and environmental backgrounds, providing a wide variety of perspectives that are important when considering what approaches can be standardized for use in policy.

2.3 Evaluating the Compatibility of Carbon Sequestration and Biodiversity Protection

There has been a great deal of discussion related to the ancillary biodiversity benefits of terrestrial carbon sequestration activities. This component of the research is being used to evaluate some of these claims, in particular, will conservation-oriented activities be cost-effective enough? Are conservation and carbon sequestration sometimes at odds? To answer these questions numerous potential conservation activities are being evaluated for both cost and carbon sequestration potential.

Conduct Feasibility Studies to Assess Compatibility of Carbon Sequestration and Biodiversity Protection. Various proposed and ongoing conservation activities being engaged in by The Nature Conservancy provide excellent case studies for assessing the potential for conservation-focussed carbon sequestration. These analyses show that in some cases conservation management activities actually result in emissions relative to a business-as-usual baseline while in other situations they result in sequestration. In those situations where conservation management results in sequestration, there is a wide difference in terms of the costs per ton of CO_2 sequestered. Where costs are high, other sources of finance, such as finance for the biodiversity benefits themselves, would need to be brought to bear for these projects to go forward. The following is a description of six of seven case studies being considered, and the status of research for these six. The final decision on the seventh case study site is still being made.

Semi-arid Grassland Restoration and Management; Apache Highlands, Arizona
This study focuses on the restoration and management of semi-arid grasslands. Past shrub encroachment has degraded the grasslands in the region. The application of fire and frequency of grazing are two tools for restoring and managing these grasslands. In this study the Century model was used to assess the soil and vegetation carbon impacts of prescribed fire and grazing frequency restoration and management scenarios. The modeling results indicate that semi-arid grassland restoration and management activities result in an increase of 5 metric tons of CO_2 equivalent per acre over 100 years when fire is not applied, and a decrease of 20 metric tons of CO_2 equivalent per acre over 100 years when fire is applied.

Native Prairie Restoration; Kankakee Sands, Indiana
This study focuses on the restoration of native sand prairie on agricultural land. The Century model was used to assess the soil and vegetation carbon impacts of restoration of prairie-savanna and mesic prairie systems. The modeling results indicate that over 100 years the mesic prairie system stores 25 additional metric tons of carbon equivalent per acre and the prairie savanna system stores 47 additional metric tons of carbon equivalent per acre. Soil samples were taken and carbon concentrations were measured using dry combustion analysis. The soil sample analyses were not conclusive and neither refuted or confirmed the Century model results. Using the Century model results, the net present value of the cost per metric ton of CO_2 equivalent (assuming a 20 year carbon contract) was calculated. The cost per ton was $83 per ton including the restoration costs (but excluding the land acquisition costs).

Mined Land Forest Restoration; Clinch and Powell River Valleys, southwest Virginia
This study focuses on native forest restoration on abandoned mined lands and lands that were previously mined and reclaimed to unproductive grasslands. A baseline analysis was completed using satellite

images to detect rates of land use change. The Virginia Department of Mines, Minerals, and Energy was consulted on the forest restoration costs and Winrock International was consulted on region-specific carbon sequestration rates. Researchers at Steven F. Austin State University were contracted to do economic analyses to determine timber management regimes to maximize timber and carbon offset revenues, based on a range of parameters. Based on the baseline results, lands with high potential for additional carbon sequestration were delineated. Lands within the region were also prioritized according to water quality improvement potential. The results allow The Nature Conservancy to prioritize carbon sequestration projects based on the potential to improve freshwater habitat for the over 30 threatened species of mussels in the Clinch and Powell River Valleys. This study is not yet complete.

Bottomland Hardwood Restoration; Mississippi Alluvial Valley: Mississippi, Louisiana, Arkansas, and small portions of Tennessee, Illinois, and Missouri
This study us underway and is focusing on the restoration of native bottomland hardwoods on marginal agricultural land in the Mississippi Alluvial Valley. Winrock International will be consulted on the carbon sequestration rates in the region. Data from USDA and from the Lower Mississippi Valley Joint Venture will be used to calculate a reforestation baseline. Local Conservancy staff and publicly available data will be consulted to determine the opportunity costs to landowners and incentives needed to stimulate reforestation on agricultural land. Leakage effects will be researched. The study will also assess the co-benefits (habitat restoration, water quality improvements, creation natural flood storage basins) of native forest restoration in the region.

Floodplain Restoration; Susquehanna River, Pennsylvania
This study will focus on the restoration of floodplain forests in the Susquehanna River watershed. Using satellite imagery a baseline of the deforestation and reforestation rates in the region will be developed. Winrock International will be consulted on the carbon sequestration rates in the study area. Local Conservancy staff will assess land acquistion/easement costs and restoration costs. Lands with potential for carbon sequestration will be prioritized according to water quality improvement potential.

Longleaf Pine Restoration; Florida
This study will focus on the restoration of longleaf pine ecosystems in Florida. Using satellite imagery, a baseline of the deforestation and reforestation rates of this system will be developed. Based on previous work carbon sequestration rates will be estimated for the study area. Local Conservancy staff will assess land acquisition/easement costs and restoration costs.

Evaluate Cost-Effectiveness of Activities that have Concurrent Climate and Biodiversity Benefit. Easy-to-use tools are needed for quick screening of specific carbon sequestration project ideas. There is currently a great interest in carbon sequestration across the United States, but little knowledge by many organizations with access to land about what is required to make a project an attractive one. An Excel-based screening tool will be developed to provide an initial screening of both the costs and sequestration potential of project ideas. The model will allow the user to quickly and easily explore general carbon sequestration potential in a variety of ecosystem types and baseline conditions found across the United States. Winrock will provide expertise on carbon monitoring methods and will develop a method for estimating monitoring costs for domestic projects. The method will be developed to be applicable to a range of project types.

The method developed for estimating monitoring costs will consider the costs of monitoring on a per area basis and if possible on a per ton of carbon basis. The cost estimates need to consider a variety of factors: i) new project ideas versus building onto existing projects, with specific consideration of baseline development costs; ii) economies of scale considering small, versus medium, versus large projects; iii) heterogeneity of the landscape as defined by number of strata; iv) the availability of local monitoring expertise; v) the accessibility of the site; vi) the level of sampling precision desired; and vii) potential cost savings associated with an "umbrella" approach ; vii) the potential for reductions in costs due to ongoing technological developments.

3.0 Conclusions

The Climate Action Project Research Initiative is helping to improve existing carbon inventory methods, create new methods where adequate methods do not exist, and compare offset estimate methods to identify those that are most cost-effective. Though this work is ongoing, preliminary results have helped to strengthen carbon inventories and have shown great promise in terms of measuring carbon pools that were either too difficult or too expensive to measure in the past. Further work is also being accomplished to establish policy-relevant baselines. Over the next year approaches will be compared and evaluated more fully.

The research also fills an important niche in exploring whether or not carbon sequestration can lead to meaningful conservation benefits. In particular, it is assessing the cost-effectiveness of various conservation activities across the U.S. in terms of the cost per ton of CO_2 emissions reduced or removed. Early results are mixed, with some conservation activities, such as prescribed burning in grasslands, leading to net emissions of CO_2, other activities leading to emissions reductions and removals that are prohibitively expensive, and still others where indeed conservation can lead to cost-effective carbon sequestration.

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